



T-Shaped Emitter Metal Structures for HBTs

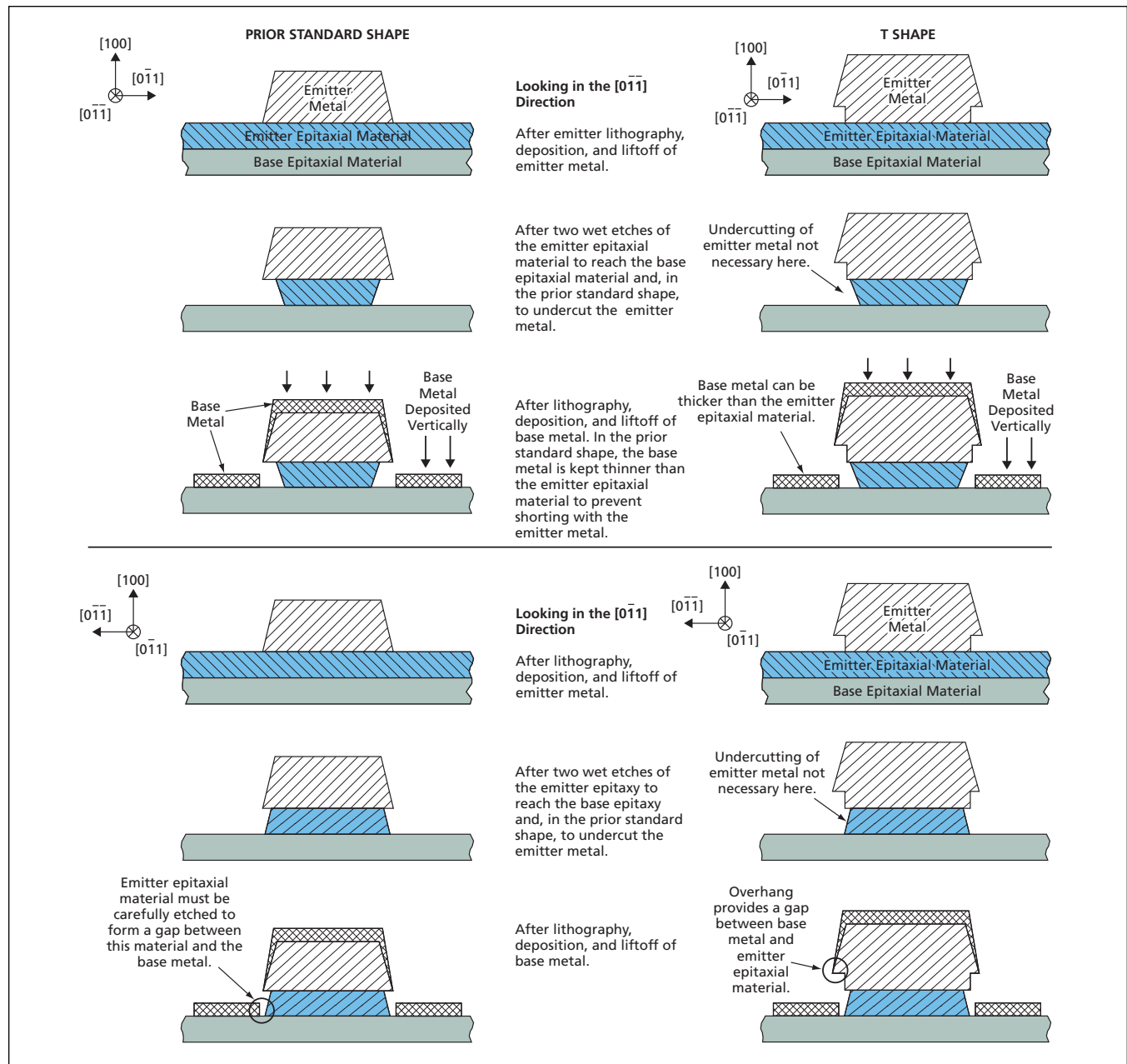
Fabrication yields are increased.

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Metal emitter structures in a class of developmental InP-based high-speed heterojunction bipolar transistors (HBTs) have been redesigned to have T-shaped cross sections. More precisely,

the modified cross sections can be characterized as having highly stylized T shapes that are modified versions of prior trapezoidal shapes (see figure). T-cross-section metal features have been

widely used in Schottky diodes and high-electron-mobility transistors, but not in HBTs. As explained below, the purpose served by the present T cross-sectional shapes is to increase fabrication yields be-



Cross Sections of Base/Emitter Junctions containing self-aligned base metal structures, in the prior standard shape and the innovative T shape, are shown here at three stages of fabrication.

yond those achievable with the prior cross-sectional shapes.

At the beginning of the program to develop these HBTs, some of the HBTs were fabricated to contain self-aligned base metal structures and some to contain non-self-aligned base metal structures. For the ones containing self-aligned base metal structures, fabrication lots exhibited low yields and high degrees of nonuniformity, which were attributable to inadequate definition of base/emitter junctions. Yields were reduced by the need to reject transistors that had leaky junctions. One of the primary causes of leakage at the junctions was short-circuiting of the base metal to emitter semiconductor epitaxial material that had not been sufficiently removed from the vicinity of the base metal during the wet-etch undercut procedure. The existence of this cause was observed in some cases from scanning electron microscopy and indirectly deduced from the observation that the yields of HBTs containing non-

self-aligned base metal structures were more than double the yields of HBTs containing self-aligned base metal structures.

The incidence of leakage is smaller in the non-self-aligned case because the base metal is spaced farther from the emitter at the outset. In contrast, in the self-aligned case, the base metal is separated from the emitter epitaxial material by only the amount of the emitter undercut effected in the aforementioned etching. Self-aligned base metal structures are preferred over non-self-aligned ones because the resulting base resistances are smaller, leading to better transistor performances.

The T-shaped cross section reduces the likelihood of short-circuiting of base metal to epitaxial emitter material, thereby helping to increase fabrication yield, in the following way: The overhang portion of the T acts as an awning-like deposition mask. The base metal is deposited predominantly unidirectionally (vertically downward in the figure)

by evaporation, and deposition is prevented or reduced in the shadow area that lies under the overhang and adjacent to the emitter epitaxial material.

The T shape also offers other benefits:

- Requirements for controlling undercut etching are relaxed; as a consequence, emitter/base definition processes are simplified.
- The relaxation of requirements makes it possible to use thicker base metal deposits, thereby reducing the inductances and the electrical and thermal resistances of base metal structures.

This work was done by King Man Fung, Lorene Samoska, James Velebir, Richard Muller, Pierre Echternach, and Peter Siegel of Caltech; Peter Smith of Cree, Inc.; Suzanne Martin of Wavestream Corp.; Roger Malik of R/JM Semiconductor; and Mark Rodwell, Miguel Urteaga, Vamsi Paidi, and Zack Griffith of UC Santa Barbara for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-41034

Rigorous Estimation of SNR of a PSK Communication Link

It is not necessary to use a separate link to assess propagation conditions.

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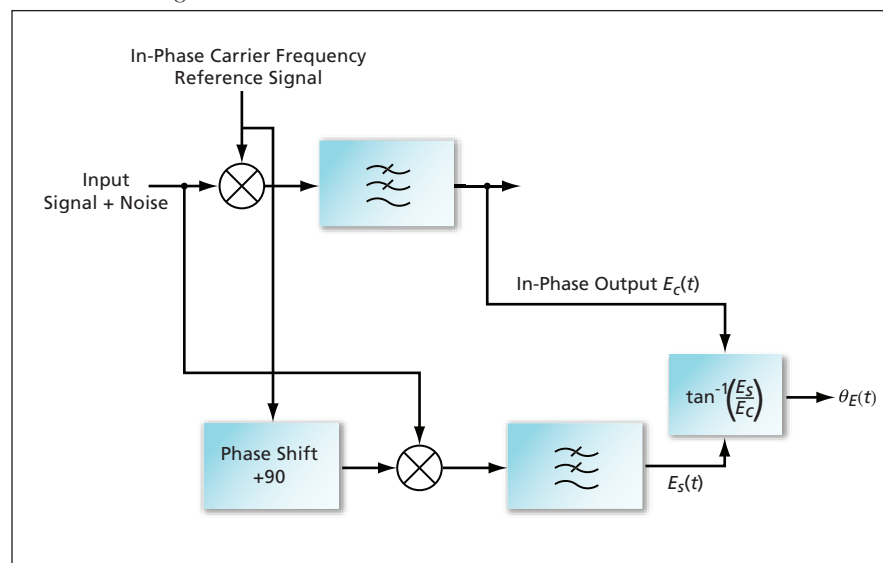
An improved method of estimating the signal-to-noise ratio (SNR) of a phase-shift keying (PSK) communication link is founded on a rigorous statistical analysis of the input to, and the output from, the PSK demodulator in the receiver. Many methods to estimate SNR ratios of PSK communication links have been developed previously, and all of them are defective (that is, not rigorous) in that all of them are based on tacit and unwarranted assumptions made for the sake of analytical simplification. In addition, some of the prior methods involve (1) the use of a separate receiver, denoted the propagation receiver, to measure a beacon signal distinct from the PSK communication signal and (2) extrapolation of the result of the measurement to an estimate the SNR of the PSK communication channel. In contrast, the improved method is free of unwarranted simplifying assumptions and does not require the use of a propagation receiver.

One basic concept shared by both the improved method and the prior methods is that the effect of noise in the communication link is not only present in the input to the demodulator but is also convolved within the

output of the demodulator. The mathematical analysis in this method is based on (1) established theories of statistical analysis of flows of the signal and noise through a generic M -ary PSK demodulator, and (2) techniques of maximum-likelihood estimation theory. In this analysis, one employs, rather than neglects, all the subtleties

of the statistics that characterize the stochastic nature of the phase-modulated signal to derive an estimation procedure that utilizes the inherent phase characteristics of the input to and the output from the demodulator.

The complexity of the analysis precludes a detailed description in this article. It must suffice to summarize as fol-



A BPSK Demodulator Is Modified to obtain the phase error, $\theta_E(t)$, in a composite signal.